APPLICATION FOR PATENT

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Title: Electrochemical Device and Method for Scale Deposition and Removal

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to an electrochemical system for removing scale from water supply systems, and, in particular, to an electrochemical system having a scale-removing scraper for removing scale from the cathode surface so as to increase the rate of scale deposition thereon.

Various systems are known for preventing scale precipitation and deposition in both hot and cold water systems. Substantially, these systems prevent the deleterious deposition and build-up of scale by precipitating the hardness in the water, so as to produce a suspended colloid. Systems known in the art utilize, inter alia, ultrasonic, magnetic, electrostatic, catalytic, and electrochemical means to reduce the undesirable precipitation of scale.

Among the known electrochemical devices are the modern and efficient systems based on the "Guldager" electrolytic method. In these systems, aluminum anodes, connected to an external electrical supply source, are immersed in metallic water tanks. The anodes are oxidized by the water, while the water becomes alkaline with high pH values close to the inner wall of the tank, precipitating calcium carbonate ($CaCO_3$) and dissolving the aluminum anodes in the water as aluminum hydroxide [$Al(OH)_3$].

In my Israeli Patent No. 120,003 is disclosed a modified Guldager system having non-dissolving electrodes made of, or coated with, a TiNiO alloy. In this system, which will be described in greater detail hereinbelow, the scale is deposited on the inner wall of the tank, and is removed by a scraping action against the wall.

It would be highly advantageous to have an improved method of, and a device for, electrochemically treating water supply systems that would further reduce the water hardness (i.e., the level of unprecipitated scale) in such systems. It would be of further advantage if the improved method and device would be simple, robust, and inexpensive.

SUMMARY OF THE INVENTION

According to the teaching of the present invention there is provided an electrochemical device for scale treatment in water supply systems, having: (a) an electrochemical cell including: (i) a metallic tank for receiving a water supply, the tank forming a cathode of the electrochemical cell; and (ii) at least one anode, disposed within the tank; the electrochemical cell being operative to produce a pH above 12 near a wall of the tank, so as to form a scale deposition on the wall, thereby removing the deposition from the water supply; (b) an elastic scraper disposed within the tank, the scraper operative for scraping the wall of the tank, and (c) a control system for the elastic scraper, designed and configured to activate the scraper so as to promote the deposition of scale on the wall.

According to another aspect of the invention, the electrochemical device for scale treatment includes: (a) an electrochemical cell having: (i) a metallic tank for receiving a water supply, the tank forming a cathode of the electrochemical cell, and (ii) at least one anode, disposed within the tank; the electrochemical cell being operative to produce a pH above 12 near a wall of the tank, so as to form a scale deposition on the wall, thereby removing the deposition from the water supply; (b) an elastic scraper disposed within the tank, the scraper operative for scraping the wall of the tank, and (c) a control system for the elastic scraper, designed and configured to supply a pre-determined constant current for activating the scraper so as to promote the scale deposition on the wall.

According to yet another aspect of the invention, there is provided an electrochemical method of scale treatment in water supply systems, the method including the steps of: (a) providing a system having: (i) an electrochemical cell including: a metallic tank for receiving a water supply, the tank forming a cathode of the electrochemical cell and an anode, disposed within the tank; (ii) an elastic scraper disposed within the tank, the scraper operative for scraping a wall of the tank; (b) operating the cell so as to operatively produce a pH above 12 near the wall of the tank, so as to form a scale precipitate on the wall, thereby removing the precipitate from the water supply, and (c) controlling an operation of the scraper so as to promote the scale deposition on the wall.

According to one preferred embodiment of the present invention, the

anode includes a material selected from the group consisting of aluminum, magnesium, and zinc.

According to another feature in the described preferred embodiments, the anode includes an alloy including TiNiO and/or a metal coated by an alloy including TiNiO.

According to still another feature of the present invention the control system is an automatic control system having a pneumatic or electrical control mechanism.

According to still another feature of the present invention, the control system includes at least one indicator for triggering the scraper to scrape the wall.

According to yet another feature in the described preferred embodiments, the indicator is for measuring a physical property associated with a thickness of the scale deposition.

According to still another feature in the described preferred embodiments of the present invention, the physical property is electrical resistance, and the control system is responsive to a differential in the electrical resistance.

According to yet another feature of the present invention, the differential in said electrical resistance is a differential of up to 3 ohms.

According to still another feature in the described preferred embodiments of the present invention, at least one indicator is designed and

configured to trigger the scraper to scrape the wall when the scale deposition attains a thickness of up to 2 mm.

According to yet another feature in the described preferred embodiments, at least one indicator is designed and configured to trigger the scraper to scrape the wall when the scale deposition attains a thickness of up to 0.5 mm.

According to still another feature in the described preferred embodiments, the control system includes a timing mechanism, designed and configured to trigger said scraper according to a pre-determined time parameter.

According to yet another feature of the present invention, the pre-determined time parameter is a fixed time interval.

According to still another feature of the present invention, the fixed time interval is up to 12 hours.

According to yet another feature in the described preferred embodiments, the fixed time interval is up to 1 hour.

According to still another feature in the described preferred embodiments of the present invention, the electrical power supply is designed and configured to supply a pre-determined constant current.

According to yet another feature of the present invention, the elastic scraper includes a circumferential elastic ring for ensuring a close contact while removing scale by the scraper.

According to still another feature in the described preferred embodiments, the control system is designed and configured to activate the scraper according to a combined function including the physical property and the pre-determined time parameter, wherein the physical property is preferably the electrical resistance or the electrical conductivity.

According to still another feature of the present invention, the electrochemical method further includes the step of measuring a physical property correlated with a thickness of the scale deposition, to obtain a measurement, wherein the controlling of the scraper operation is at least partially based on said measurement.

Finally, according to yet another feature in the described preferred embodiments of the present invention, the physical property is selected from the group consisting of electrical resistance and electrical conductivity.

Thus, the present invention successfully addresses the shortcomings of the prior art by providing a simple robust and inexpensive improved method of, and device for, electrochemically treating water supply systems that further reduce the water hardness (i.e., the level of unprecipitated scale) in such systems.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

In the drawings:

FIG. 1 is a schematic cross-sectional view of the inventive electrochemical device having a scale scraper for removing scale from water supply systems.

FIG. 2 is a graph comparing the level of water hardness (expressed as ppm of dissolved calcium) attained using: a constant voltage device (device A) of the prior art; a similar device having a scraper of the prior art (device B), and an inventive device (device C) having a novel scraping technology and operating at constant current.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is a method of, and device for, electrochemically treating water supply systems so as to greatly reduce the water hardness with respect to similar, known electrochemical water treatment systems. The inventive device effectively induces scale to precipitate on the inner wall of the water treatment tank.

The principles and operation of the system and method according to the present invention may be better understood with reference to the drawings and the accompanying description.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawing. The invention is capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

In my Israeli Patent No. 120,003 is disclosed a modified Guldager system having non-dissolving electrodes made of, or coated with, a TiNiO alloy. In this system, the scale is deposited on the inner wall of the tank, and is removed by a scraping action against the wall.

Referring now to the drawings, FIG. 1 is a schematic cross-sectional

view of an improved electrochemical device having a scale scraper for removing scale from water in a water supply system. Electrochemical device **100** includes a cathode-wall **20** of metallic water tank **12**, and at least one, and typically, at least two anodes **10a** and **10b** attached to cover **14**, disposed longitudinally in tank **12**, and typically extend almost to the bottom **16** thereof.

According to yet another feature in the described preferred embodiments, Anodes **10a** and **10b** are made of aluminum, or preferably of TiNiO thus enabling the delivery of high electrical currents to the electrochemical cell, without dissolving anodes **10a** and **10b** and consequently, without contaminating the treated water with undesirable metal ions and colloidal sludge.

When current is delivered to the electrochemical cell via an electrical power supply **18**, the water close to wall **20** attains high pH values (typically, 12 to 14). Consequently, various dissolved carbonates and metal oxides in the water within tank **12** precipitate on wall **20**. Power supply **18**, which is designed and configured to supply a constant current, preferably supplies a direct current. It should be emphasized that in prior art constant voltage devices, the scale layer growth increases the electrical resistance, consequently reducing the electrical current and scale deposition rate. In sharp contradiction to constant voltage devices, constant current operation of electrochemical device **100** enables to deposit scale **24** at a substantially constant, high rate. During the deposition, scale layer growth causes an increase in electrical

resistance, and hence in the voltage required to keep constant electrical current that ensures constant scale deposition rate.

As disclosed in my Israeli Patent No. 120,003, tank **12** includes a scraper **22** that mechanically cleans and removes scale **24** that is deposited on wall **20**. Scraper **22** consists of a disc **44**, typically, but not necessarily, metallic, designed and configured with adjustable openings that enable the installment of anodes **10a** and **10b**, and enable free movement of scraper **22**.

Whenever scale cleaning is desired or needed, the water flow is stopped by closing inlet valve **32,** scraper **22** is moved slowly downwards by piston **28** (installed in a piston housing **30**) so as to scrape off scale **24** from inner wall **20**. When scraper **22** reaches its lowest position, draining valve **26** is opened and the slurry of loose particles and water is drained out. After draining, water tank **12** is thoroughly rinsed by opening water inlet valve **32**, while water outlet valve **34**, which is a 3-way valve, is diverted to drain the water out of the system until clear water comes out. After thoroughly rinsing the tank, scraper **22** is raised back to its normal position, and outlet valve **34** returns to a normal operating position, such that feed water again flows into the system.

Table 1 and FIG. 2 describe a typical experiment that was conducted to test the performance of the present invention in comparison to prior art devices. In the experiment, feed water was electrochemically treated using one of three devices: an ordinary constant voltage device (device A), a similar device equipped with a scale scraper (device B), and by electrochemical device

100 of the present invention. Table 1 records the water hardness (in ppm) achieved in these devices during each day of operation. Column A relates to device A, Column B to device B, and Column C to device **100**. The measurements given in Table 1 are also provided graphically in FIG. 2 as curves A, B and C, respectively.

<u>Table 1</u>

Water hardness (ppm calcium) in the devices vs. day of operation

Days	Calcium Hardness (ppm $CaCO_3$)		
	A	B	C
1	243	243	243
2	230	218	170
3	225	206	110
4	205	170	85
5	228	180	68
6	210	180	52
7	205	170	67
8	220	205	51
9	200	175	65
10	225	170	53

It is observed from Table 1 and FIG. 2 that while device A gradually

reduced the water hardness from 243 ppm to 205 ppm over the first 4 days of operation, no further reduction was achieved thereafter. Device B, which was equipped with a prior-art scraping mechanism (as taught by my Israel Patent No. 120,003), exhibited an improved scale-precipitating performance, reducing the water hardness from 243 ppm to 170 ppm over the first 4 days of operation. However, no further reduction was achieved thereafter.

Until recently, the known function of scraper **22** was to periodically remove scale **24** from the inner wall **20** of tank **12**, so as to prevent an excessive build-up of scale. In my co-pending, unpublished (and as such, is not to be construed as prior art with regard to the present application) Israeli Patent Application Serial No. 151,181, which is incorporated by reference for all purposes as if fully set forth herein, it is taught that when the thickness of the precipitated salts reaches about 0.3 - 0.5 cm, the electrical resistance reaches unacceptably high values and scale cleaning is necessary.

Surprisingly, it has been discovered by the inventor that careful monitoring and control of the scraping operation for removing scale **24** from wall **20** (the cathode of the electrochemical cell) of tank **12** greatly increase the rate of scale deposition on the surface of the wall, such that the level of unprecipitated scale in the water being processed is appreciably reduced.

The control scheme is preferably based on a physical parameter associated with, or correlated to, the depth of crystallized scale **24**.

Control system **36** is advantageously installed, along with power supply

18, in panel **38**. Control system **36** may be an automatic (using, by way of example, a pneumatic or electrical mechanism) control system. Various indicators can be used to trigger the operation of piston **28**. These indicators may measure electrical resistance or conductivity, which largely depend on the depth of crystallized scale **24**, etc.

Although the electrical conductivity of water may vary from location to location, and from process to process, it has been discovered by the inventor that an increase in electrical resistance of up to 3 ohms indicates that scraper **22** (by means of piston **28**) should be operated to scrape scale **24** from the inner wall **20** of tank **12**. Preferably, an increase in electrical resistance of up to 2 ohms, and more preferably, up to 1 ohm, should be used as a control criterion for activating scraper **22**.

As used herein in the specification and in the claims section that follows, the term "differential" or "increase", with respect to electrical resistance within the electrochemical cell, refers to the difference between the electrical resistance at any given time and a reference or baseline electrical resistance. Preferably, the reference electrical resistance is the electrical resistance after a previous scraping, most preferably the immediately previous scraping.

In another preferred embodiment, control system **36** includes a timer **40** (also located in panel **38**), for activating scraper **22** based on pre-determined time settings, e.g., at a fixed time interval. The time interval between cleaning

of inner wall **20** should be less than 12 hours, preferably less than 4 hours, more preferably less than 2 hours, and most preferably less than around 1 hour.

As used herein in the specification and in the claims section that follows, the term "fixed time interval", with respect to a scraping operation, refers to a time interval between two successive scrapings.

It must be emphasized that control systems based both on electrical resistance (or another parameter correlated with scale deposition thickness) and time interval achieve superior results in terms of the rate of scale deposition on inner wall **20**. Specifically, it has been found that by augmenting the electrical resistance criterion with a maximum time elapsed between scrapings criterion greatly improves the performance.

When the sole criterion for activating the scraper is electrical resistance, I have found that the rate of scale deposition often decreases with time. Without wishing to be bound by theory, I attribute this decrease to various surface effects on the crystalline scale surface, including sliming, which reduce the effective surface area of scale crystals that is available for enhancing additional scale deposition. Such surface effects appear to have little effect on electrical resistance.

Hence, by incorporating an additional criterion – that of maximum time elapsed between scrapings, the deleterious surface effects on the crystalline scale surface are curtailed, and the rate of scale deposition remains substantially constant over time.

In another preferred embodiment of the present invention, scraper **22** of device **100** is equipped with a scale-cropping element for reducing the thickness of the scale deposition on inner wall **20** to a pre-determined thickness. In FIG. 1, the specific, non-limiting embodiment of the scale-cropping element is circumferential elastic ring **46**. Elastic ring **46** may be bonded to scraper **22**, or may be manufactured as an integral part of scraper **22**. Elastic ring **46** is preferably made of rubber or another elastomeric material, including, but not limited to, neoprene, butyl rubber and/or butadiene.

Equipped with elastic ring **46**, device **100** is capable of removing scale **24**, such that there remains only a thin layer of scale of up to 2000 microns, preferably less than 800 microns, and more preferably less than 500 microns. As a result, after each scraping operation, device **100** returns to working conditions at which the maximum scale deposition rate is observed.

Referring back to Table 1 and FIG. 2, it is observed that by sharp contrast to devices A and B of the prior art, device C (device **100** of FIG. 1) sharply reduces the concentration of dissolved calcium after the first 4 days of operation, from an initial concentration of 243 ppm to only 85 ppm. Moreover, the concentration of dissolved calcium continues to drop, stabilizing at a level of about 55 ppm over the next six days of operation.

The concentration of dissolved calcium achieved – 55 ppm, is substantially and surprisingly lower than the 170 ppm dissolved calcium achieved using a similar, scraper-equipped unit of the prior art. The inventive

device attained a reduction in the concentration of dissolved calcium of 77%, which compares quite favorably to the 30% reduction attained using the most similar unit of the prior art.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims. All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention.